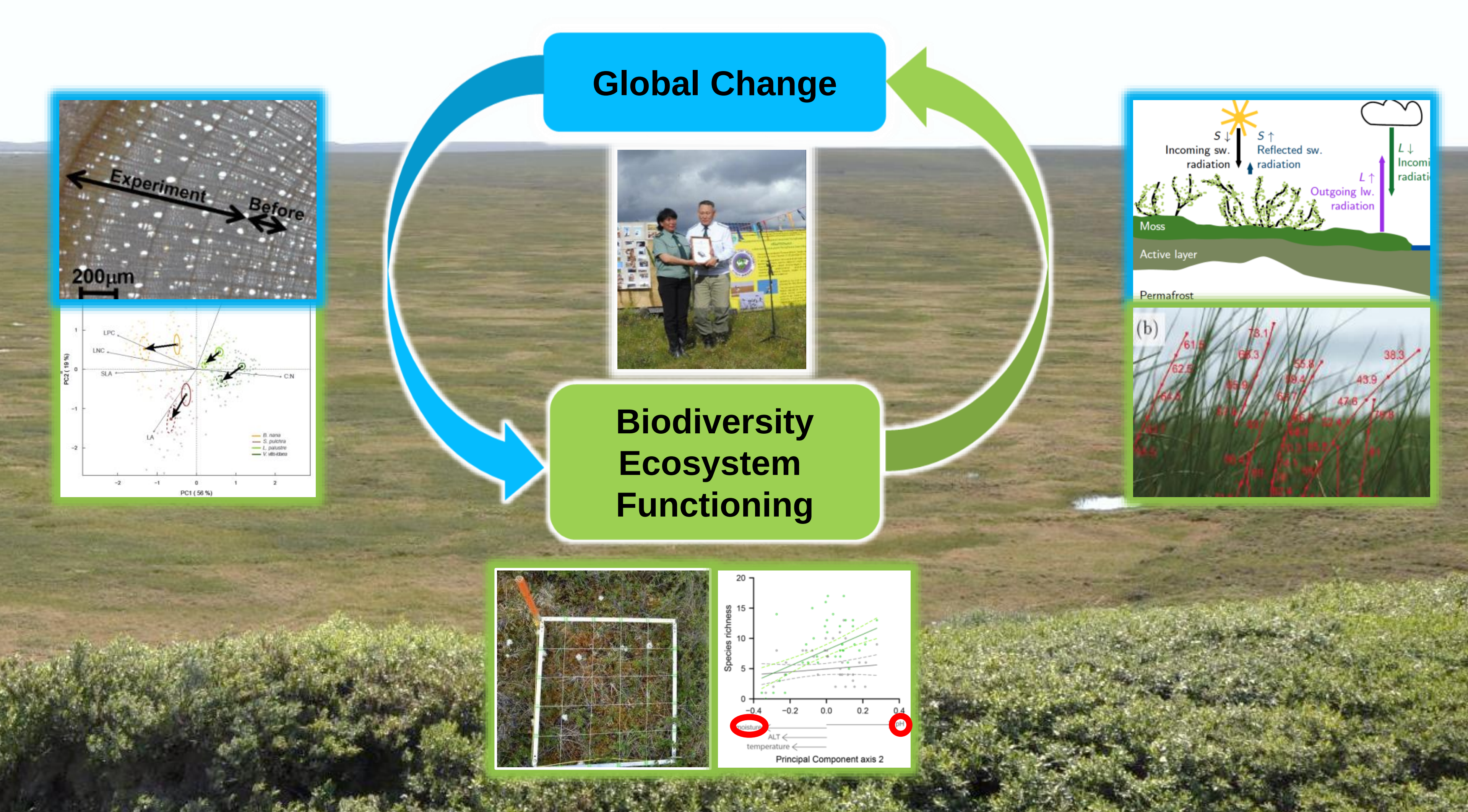
Tundra Energy Fluxes – Effects of Changing Vegetation

Gabriela Schaepman-Strub, Univ. of Zurich

gabriela.Schaepman@ieu.uzh.ch;

http://www.ieu.uzh.ch/en/research/ecology/spatial.html

IASAO Atm-Surface Exchanges WG, 08 Nov. 2017



Content

A. Introduction to Siberian tundra research site & research questions

B. Methods and results of energy flux measurements and 3D radative modelling

C. Outlook & questions

A. Kytalyk – a NE Siberian tundra research site

71°N 147°E

- Indigirka lowlands, 10m a.s.l.
- (Sub-) Arctic tundra
- Cold (MAT -13°C) and dry (MAP 232mm)
- Continuous permafrost
- Closest village Chokurdakh (30km) – meteo data since 1950s
- Kytalyk nature reserve

A. Kytalyk – a NE Siberian tundra research site

- INTERACT – International Network for Terrestrial Research and Monitoring in the Arctic (Chokurdakh station), T. Maximov, Yakutsk (SBRAS and NEFU).
- Carbon flux (CO2 & CH4) measurements (chambers & eddy covariance) and research (vegetated land surface and lake emissions) since 2003 (mostly summer) by Free U. Amsterdam (H. Dolman, K. van Huissteden).
- Vegetation removal and permafrost thawing experiment by Wageningen University (M. Heijmans, G. Schaepman-Strub).
- Soil analysis by Alfred Wegener Institute (Schirrmeister et al.)
- Energy flux observations and modelling, biodiversity monitoring by Unversity of Zurich (G. Schaepman-Strub).

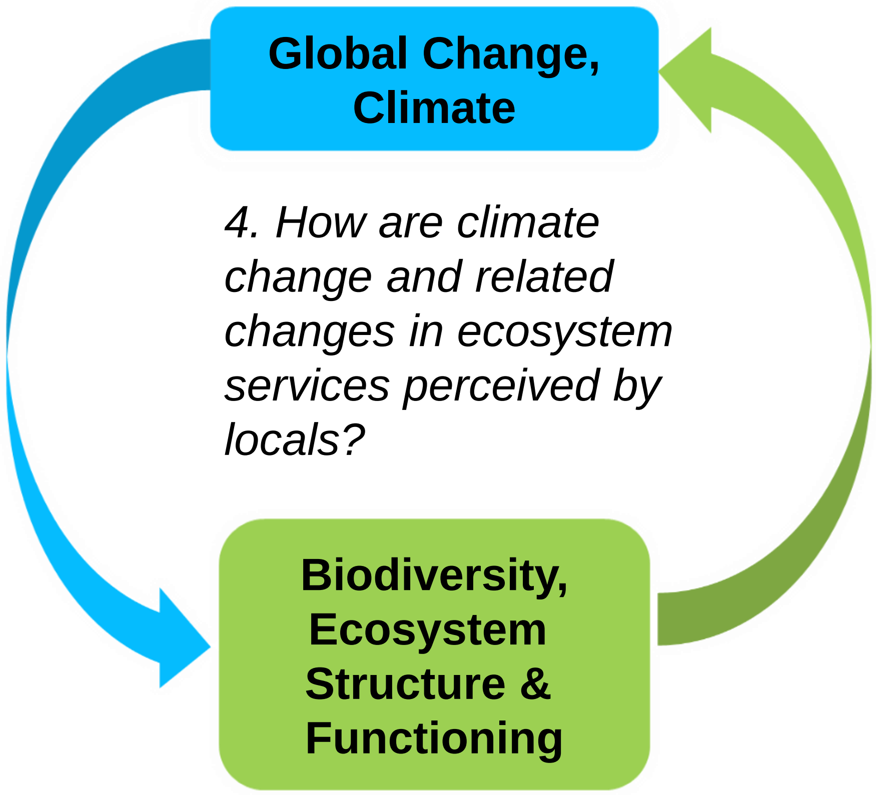
A. Kytalyk – new instrumentation (2018)

Meteo tower renewal planned for 2018 (lead by Free U. Amsterdam)

- Eddy Covariance (keep Licor 7500, 7700; Gill R3-50 -> METEK uSonic-3 Class A)
- Thermocouples (HT762 -> Barani ‘MeteoTemp’)
- Wind speed cupanemometer A100R -> heated Vector Instruments
- Wind direction (WP200 -> Vector Instr.)
- SW radiation (in, out) (K&Z CMP7B -> CMP21 or CMP10/11)
- LW radiation (keep Eppley PIR, but new calibration)
- Soil temperature (keep 107 Temp probe Campbell)
- Heat flux (keep Hukseflux HFP01)
- Barometeric pressure (keep First Sensors DS_Standard-144S-PCB)
- Rainfall (ARG100 -> Youngusa 0.1mm resolution)
- Waterlevel (First Sensors)
- Snow Depth (Campbell SR50A)

A. Research Questions

1. *What are drivers of vegetation change? How are vegetation traits changing?*



4. How are climate change and related changes in ecosystem services perceived by locals?

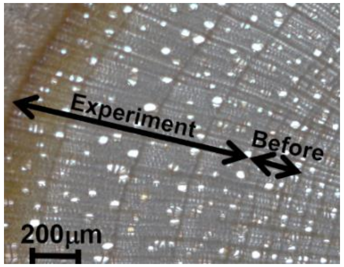
3. How do changes in biodiversity feed back to ecosystem functioning, permafrost, and climate?

2. Assessment and prediction of biodiversity - from plot to landscape to pan-arctic scale

Research Methods and Techniques

Global Change

Biodiversity



Drivers of vegetation change?

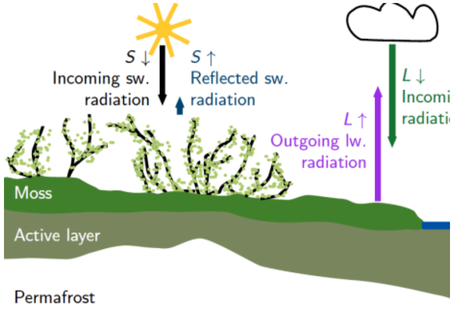
Experiments

- soil warming
- fertilization

Perception of climate and biodiversity change and impact on livelihoods?

Interviews with local people

- qualitative
- quantitative



Vegetation feedbacks to climate through energy & carbon fluxes?

- measurements
- 3D radiative transfer model
- leaf to landscape scale

Tundra biodiversity and ecosystem functioning?

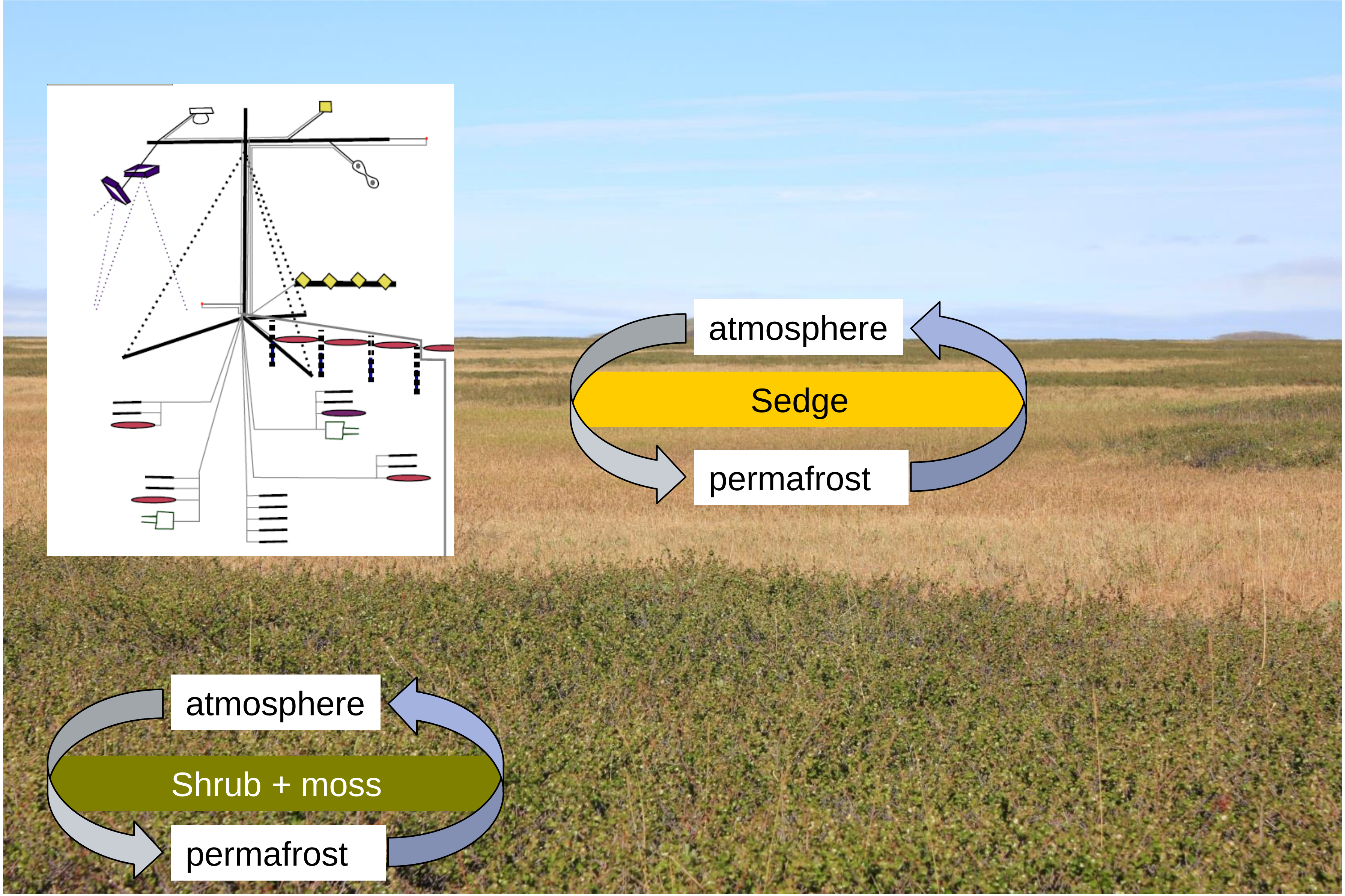
- plant species composition
- functional traits
- vegetation and lake mapping

Research Methods and Techniques

1. *Experimental (e.g. warming and precipitation manipulation)*
2. *Observational (field relevees to drone and satellite data)*
3. *Physical modelling (3D radiative transfer modelling of canopies)*
4. *… and their integration (e.g. radiative transfer modelling parameterized and validated with experimental and observational data)*

Strong international pan-arctic integration of data and methods

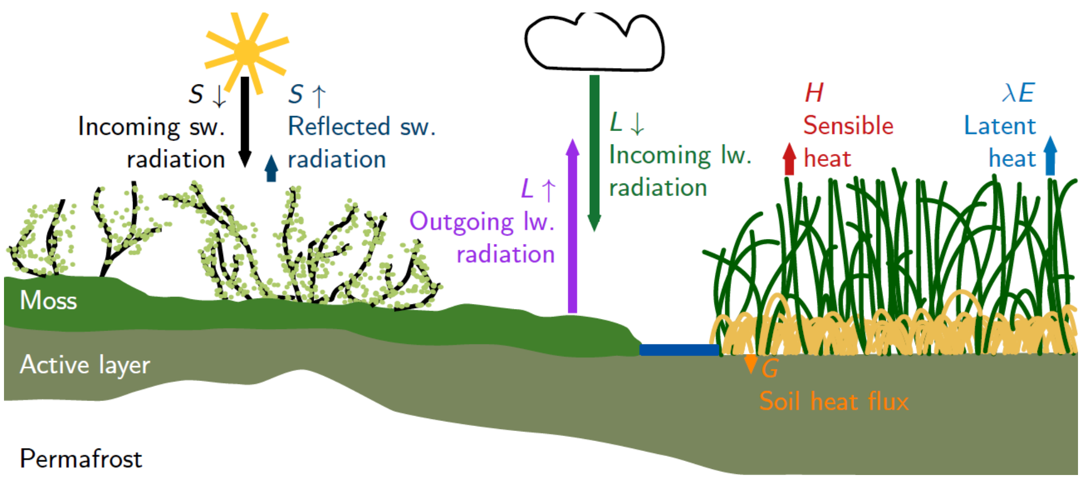
Vegetation Feedbacks to Climate through Energy Fluxes



Feedbacks to Climate Change through Energy Fluxes

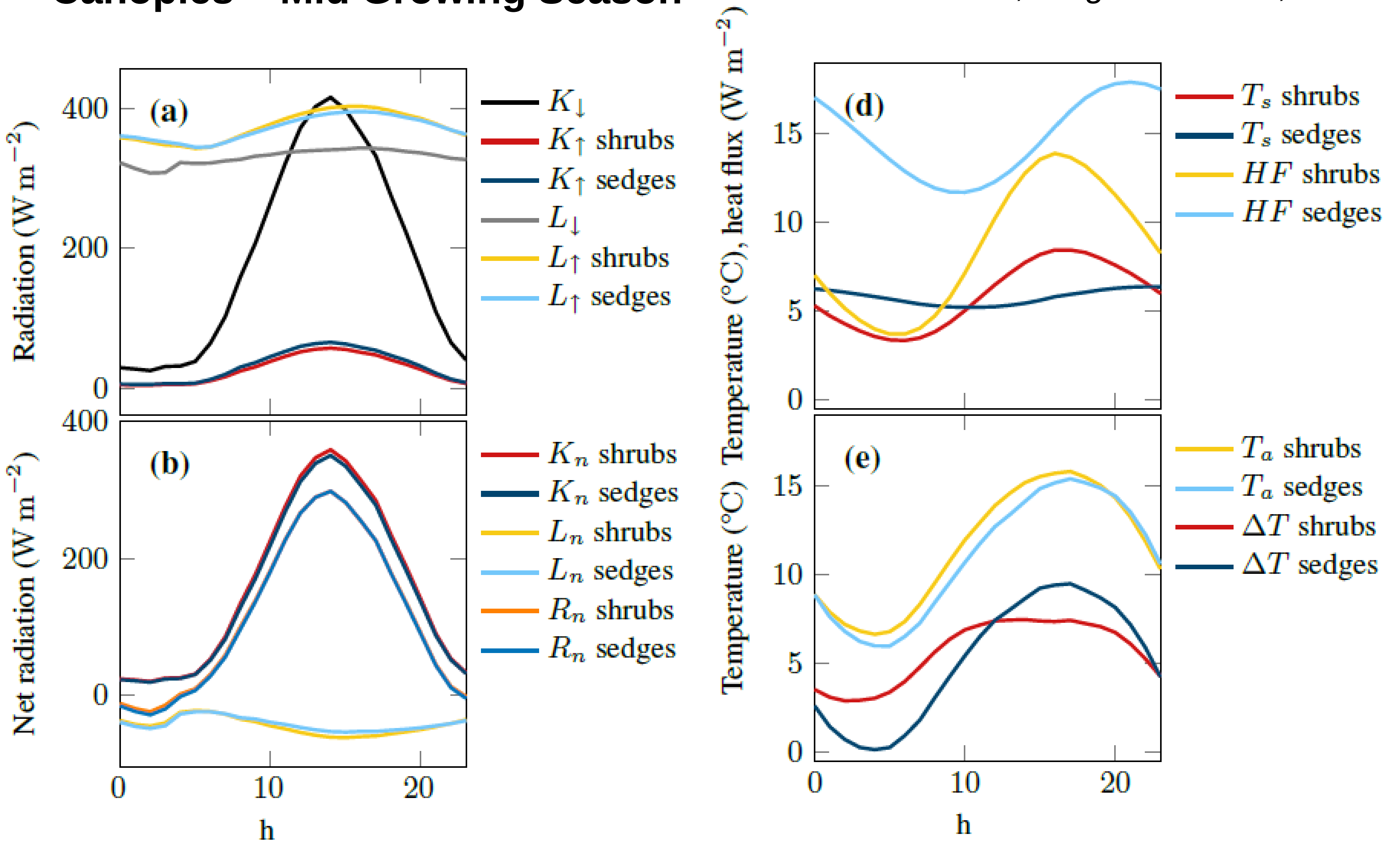
Main topic – How do vegetation types contribute to the integrated landscape fluxes? How would a potential shrubification change the energy fluxes?

1. How do above-ground radiation and soil heat flux vary with vegetation type?
   🕮 *Juszak et al., Biogeosciences, 2016*
2. How does shrub density influence albedo and transmittance?
   🕮 *Juszak et al., Remote Sensing of Environment, 2014*
3. How does patchiness of vegetation types influence shortwave radiation at landscape scale?
   🕮 *Juszak et al., Remote Sensing of Environment, 2017*



Daily Mean Energy Fluxes in Wet Sedge and Dwarf Shrub Canopies – Mid Growing Season

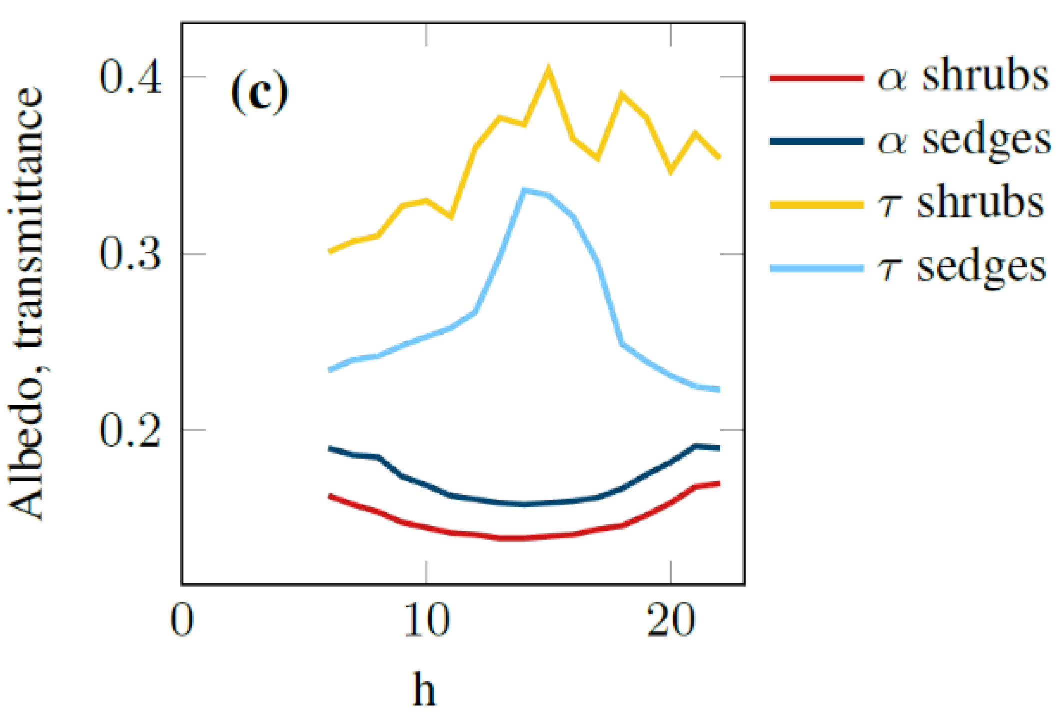
Juszak et al., Biogeosciences, 2016

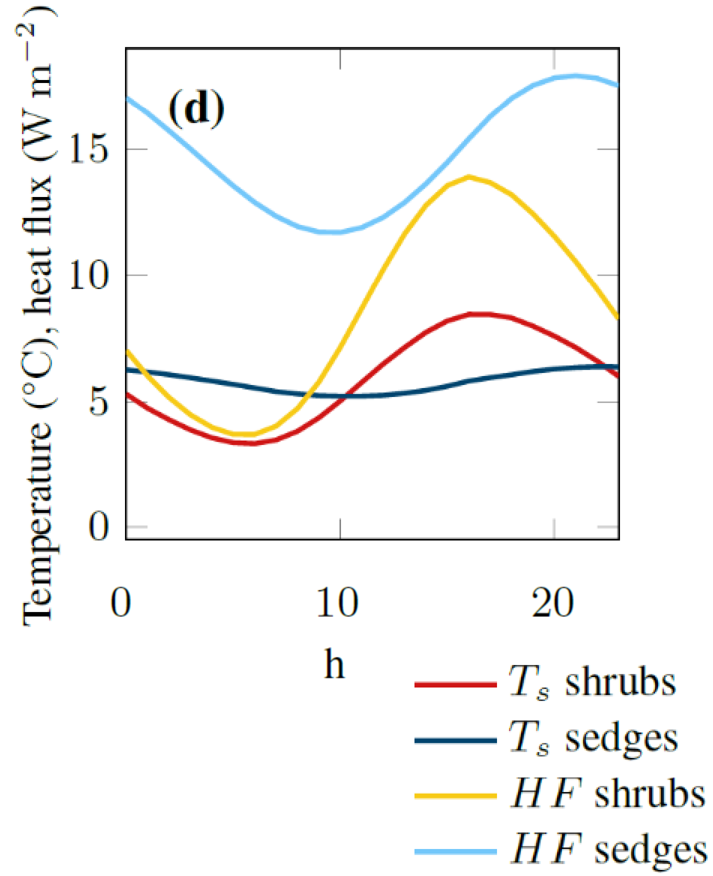


a) above-canopy shortwave (K), longwave (L) radiation fluxes, b) net radiation

d) soil temp at 4cm depth and soil heat flux 10cm depth, e) air temp at 1.7m above soil surface, difference of air and soil temp

Vegetation Feedbacks to Climate through Energy Fluxes





Albedo **shrub < sedge**

Transm. **shrub > sedge**

BUT

Ground heat flux & ALT below

shrub << sedge

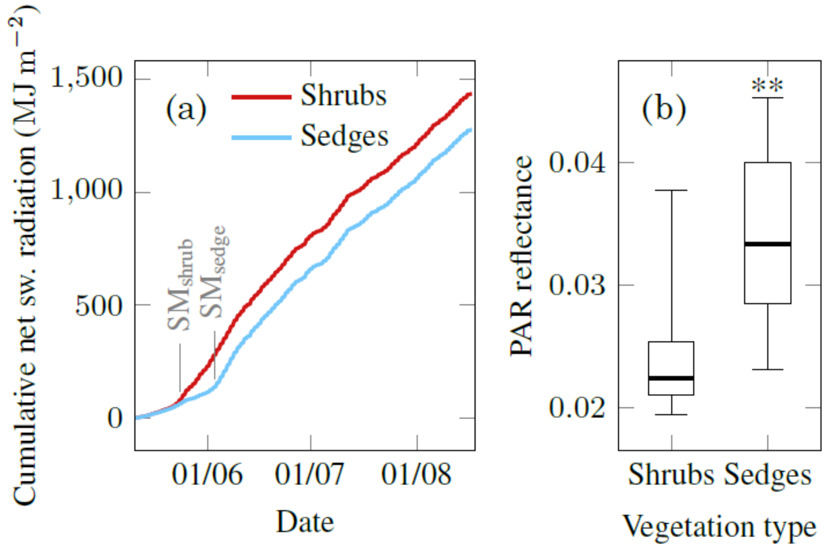
Shrubs have limited effect on permafrost thaw through shading!

Juszak et al., BG 2016

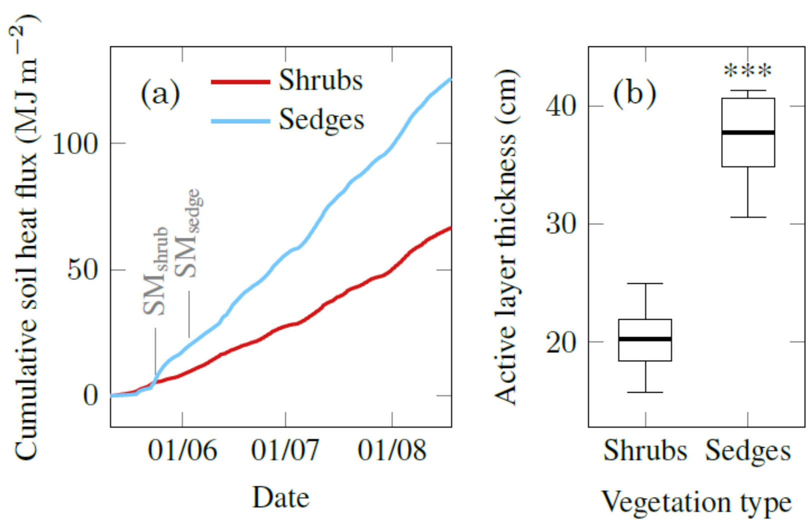

Phenological Camera
28.05.2016
01.06.2016
04.06.2016
13.06.2016
19.06.2016
25.06.2016
18.07.2016
09.08.2016
05.09.2015

Growing Season Energy Fluxes in Wet Sedge and Dwarf Shrub Canopies

above ground



below ground

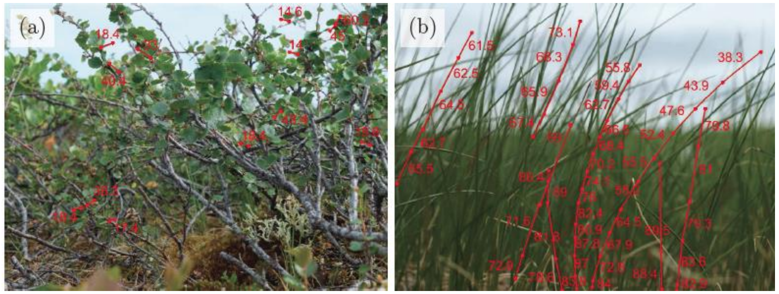


Juszak et al., Biogeosciences, 2016

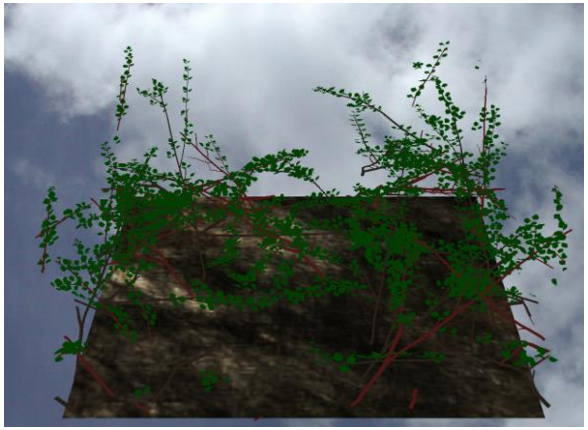
Discussion Radiation Fluxes Wet Sedge – Dwarf Shrubs

- Shrubs absorb more shortwave radiation and transmit more to the ground surface!
- Shading of sedges mostly by litter.
- Heat flux below sedges much higher than below dwarf shrubs -> heat flux and active layer thickness more controlled by local soil factors than by differences in shortwave radiation at soil surface between vegetation types.
- Processes at very local scale, posing challenges to land surface models that do not model processes at these scales.

3D Radiative Transfer Modelling - DART (discrete anisotropic radiative transfer)



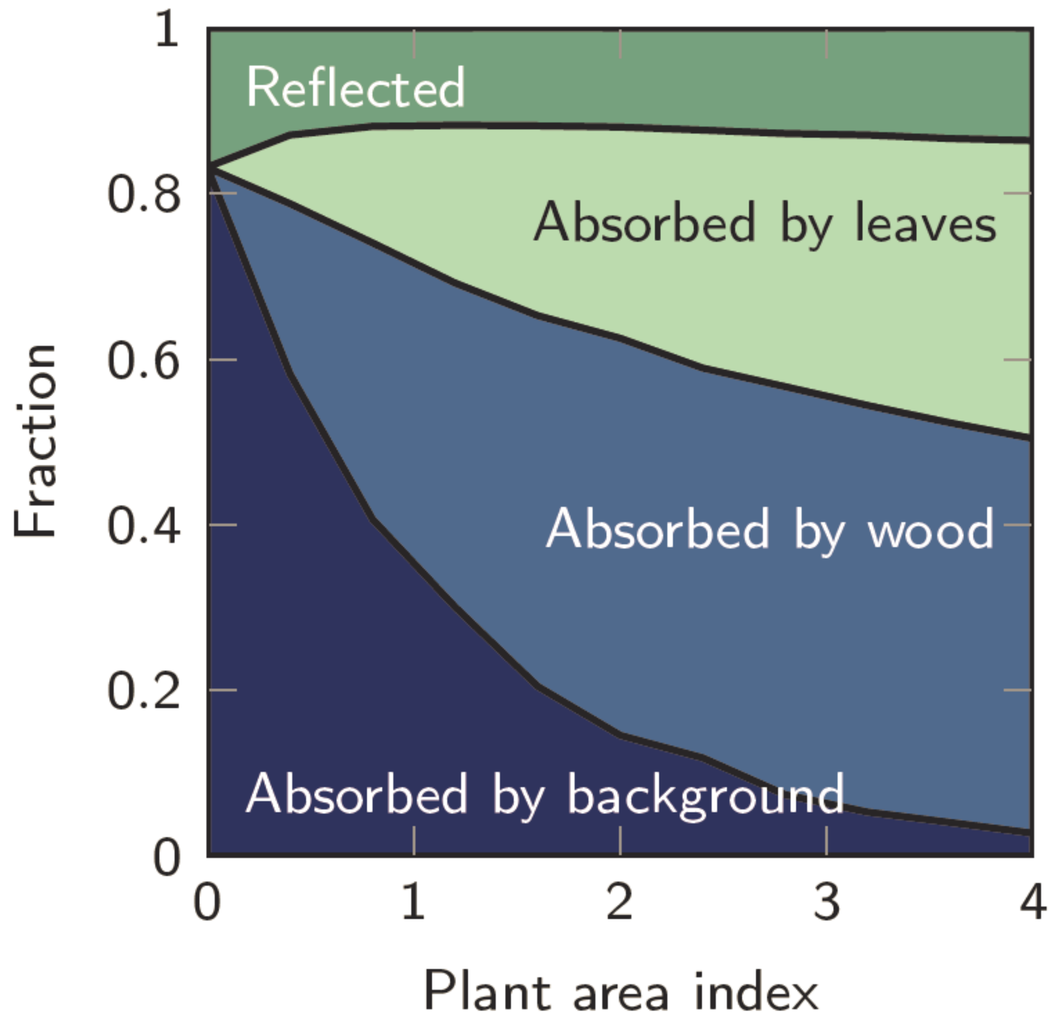
Variable	Method
Measured model input	
Leaf area index of dwarf birch (LAI)	Point-quadrant grid
Branch area index of dwarf birch (BAI)	Point-quadrant grid
Canopy height	Point-quadrant grid
Number of dwarf birch stems	Count on removal plots
Number of dwarf birch leaves	Count on removal plots
Dwarf birch branch structure	Manual measurements, photos
Leaf spectral reflectance	ASD (contact probe)
Branch spectral reflectance	ASD (contact probe)
Background reflectance	ASD (nadir, 1 m, 5° field of view)



Effect of Plant Area on SW Radiation

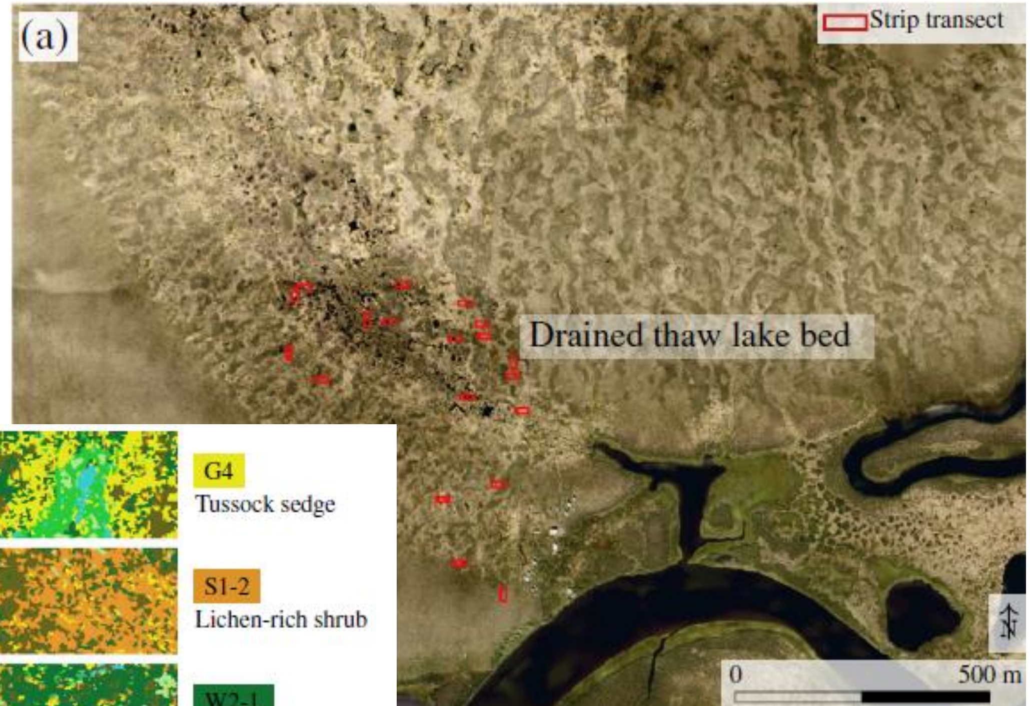
- Branches are important absorbers! They are a key component in the radiative transfer of shrub-dominated areas in the tundra.
- Increasing shrub density > PAI 1 does not decrease albedo
- Albedo insensitive to total plant area, but radiation absorption partitioning critically influenced by wood:leaf ratio.

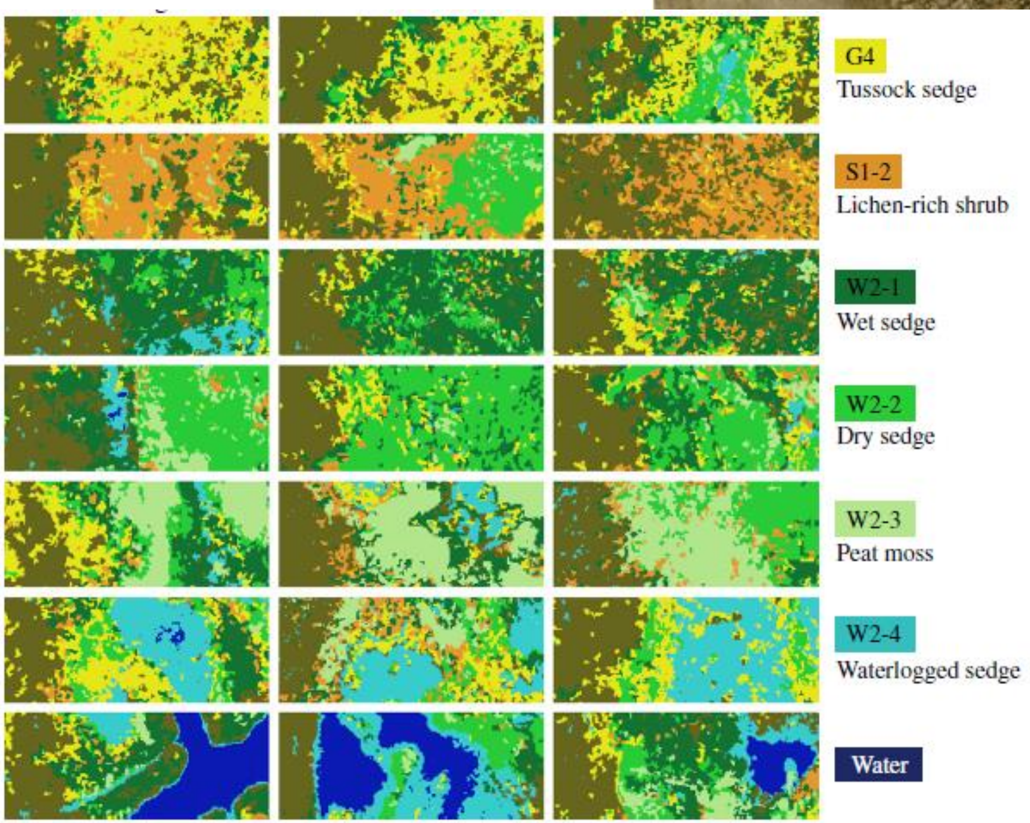
LAI = BAI, PAI = LAI + BAI



Juszak et al., Remote Sensing of Environment, 2014

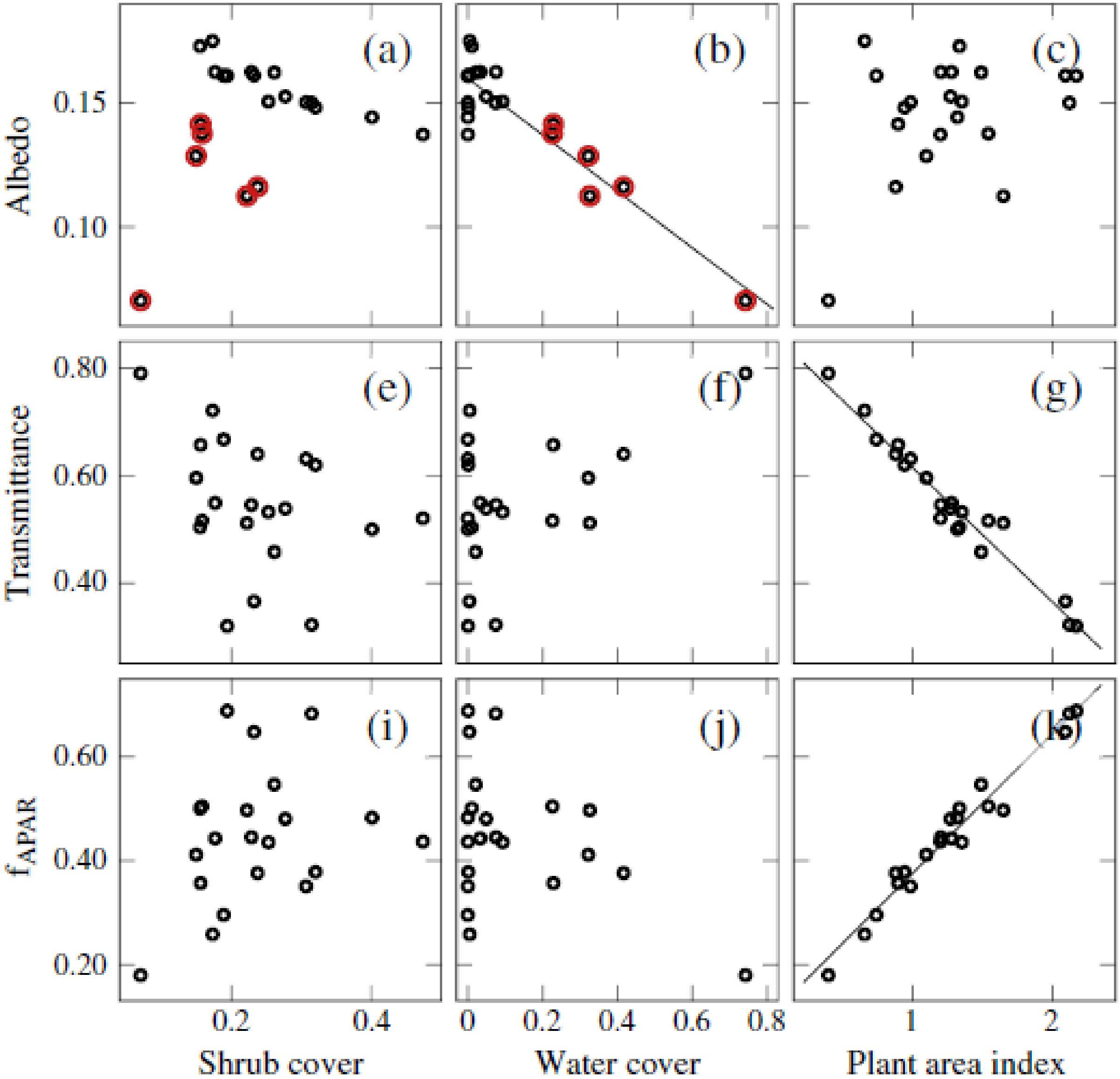
3D Radiative Transfer Modelling of Shortwave Radiation at Landscape Scale





Juszak et al, RSE, 2017

Drivers of Shortwave Radiation at Landscape Scale



water cover, shrub cover

plant area index

plant area index

Juszak et al., RSE, 2016

Discussion Landscape Albedo Results

- Surface water as primary control of landscape albedo in the studied area.
- Shrub cover of next importance, plant area not statistically significant.

- ➢ Hydrological changes in Arctic landscapes might be as important or more important to regulate albedo than vegetation changes (i.e. shrubification). But vegetation impacts partitioning of absorbed radiation (but we still miss vegetation type specific evapotranspiration measurements for tundra).
- ➢ Precipitation and permafrost degradation effects on hydrology highly uncertain (Walvoord & Kurylyk, 2016).
- ➢ Warming experiments quite wide-spread, but precipitation experiments very rare.

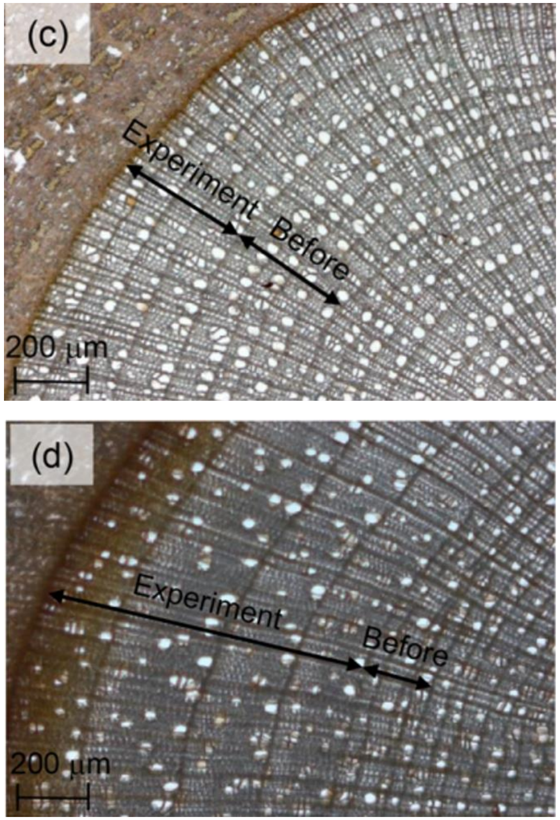
3. Outlook

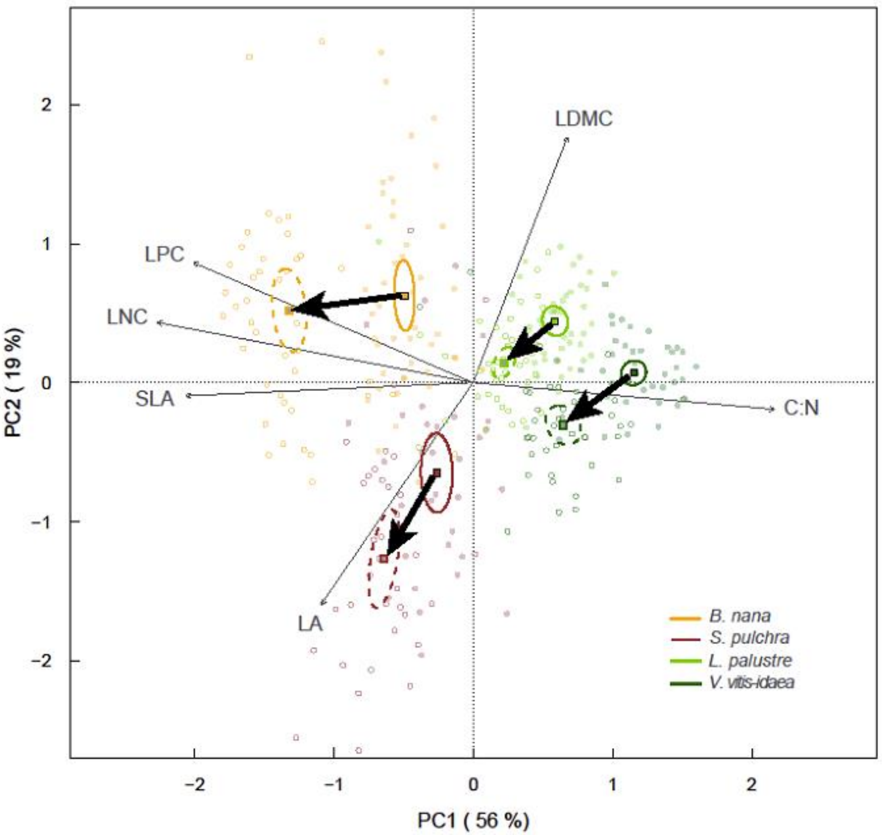
How will changing soil moisture impact vegetation and soil heat fluxes?

3. Outlook: Can we predict ecosytem responses to environmental change based on traits of species?

Experiment: Permafrost thawing and soil fertilization

Results: Conservative -> acquisitive strategy & coordinated trait response





Iturrate-Garcia, Dendrochr., 2017

Iturrate-Garcia et al., in prep

3. Questions

1. International protocols for tundra energy flux measurements (instrumentation, installation, data archiving)?

2. International collaboration of the IASAO group, coordination of energy flux research agenda in Arctic programmes?

Where I am involved (who else is?):

- Swiss representative in the International Arctic Science Committee (IASC), terrestrial working group -> seed money for workshops (e.g. Polar2018 Davos or Arctic Science Summit 2019)
- Arctic Council activities (SAON?)
- Link to satellite data community (past chair Land Product Validation subgroup, CEOS-LPV)

Thank you for listening and discussing!

References

- Iturrate-Garcia, M., et al., (2017), Shrub growth rate and bark responses to soil warming and nutrient addition – an experimental dendroecological approach, Dendrochronlogia, 45, 12-22.
- Loew, A., et al., (2017), Validation of earth observation data products - a review, Review of Geophysics, 55.
- Juszak, I., et al., (2017), Drivers of shortwave radiation fluxes in Arctic tundra across scales. *Remote Sensing of Environment*, 193, 86-102.
- Wang, P., et al., (2017), Above and belowground responses of four tundra plant functional types to deep soil heating and surface soil fertilization, *Journal of Ecology*, 105, 947-957.
- Juszak, I., et al., (2016), Contrasting radiation and soil heat fluxes in Arctic shrub and wet sedge tundra. *Biogeosciences,* 13, 4049-4064.
- Juszak, I., et al., (2014), Arctic shrub effects on NDVI, summer albedo and soil shading. *Remote Sensing of Environment*, 153, 79-89.
- Blok, D., et al., (2011), The Cooling Capacity of Mosses: Controls on Water and Energy Fluxes in a Siberian Tundra Site, *Ecosystems*, 1-11.
- Blok, D., et al., (2010), Shrub expansion may reduce summer permafrost thaw in Siberian tundra. *Global Change Biology,* 16, 1296-1305, 2010.

DART: A 3D Model for Remote Sensing Images and Radiative Budget of Earth Surfaces

J.P. Gastellu-Etchegorry, E. Grau and N. Lauret
CESBIO - CNES, CNRS (UMR 5126), IRD, Université de Toulouse, Toulouse, France

InTech, 2012